Introduction

Peripheral arterial disease (PAD) is an important health problem with a high prevalence in the industrialized world, Conventional digital subtraction angiography (DSA) has been considered the gold-standard technique in the assessment of PAD ***(Hiatt, 2001).***

Digital subtraction angiography (DSA), the standard of reference in the evaluation of lower extremity arterial disease, is an invasive procedure with substantial costs and a small risk of complications. Noninvasive techniques for anatomic assessment of the peripheral arteries that could replace DSA are therefore desirable. For this reason, noninvasive techniques such as magnetic resonance (MR) angiography and computed tomographic (CT) angiography are increasingly used in the assessment of lower extremity arterial disease ***(Majanka et al.,2007).***

Over the years, results of several studies have been published that validate contrast material–enhanced CT angiography as a noninvasive alternative to conventional DSA for imaging the vascular tree. Most studies in which single-section CT angiography was evaluated reported high estimates of sensitivity (range, 73%–100%) and specificity (range, 94%–100%) in the assessment of lower extremity arterial disease; however, they also identified problems of limited scan coverage and resolution ***(Majanka et al.,2007).***

Since the advent of hardware with multiple detectors, spatial and temporal resolution could be improved, allowing the depiction of the entire vascular tree, including the inflow and runoff arteries. Further advances in CT angiography technology resulted in an increased number of detector rows, enabling thinner collimation, faster scan speed, and improved tube capacity, which could improve the diagnostic performance of this modality. ***(Martin et al., 2003).***

The main advantages of this novel technology are the exceptionally fast scan times, high spatial resolution, increased anatomic coverage, and capability to generate high-quality multiplanar reformations and three-dimensional (3-D) renderings from raw data that can be reprocessed easily and quickly. The applications of MDCT in imaging the lower extremities are multiple and varied. They include the evaluation of peripheral arterial occlusive and aneurysmal disease, the patency and integrity of bypass grafts, and arterial injury owing to trauma. This article describes the techniques of lower extremity MDCT angiography and its use in a few clinical applications ***(Hiatt et al., 2005).***

The advantages of multidetector CT angiography over MR angiography are the relatively short imaging time and lower cost. MR angiography is contraindicated in patients with claustrophobia or metal implants. Other limitations of MR angiography include slow flow that mimics stenosis and limitations in spatial resolution. Disadvantages of multidetector CT angiography include the use of radiation and the presence of severe calcifications that may cause overestimation of stenosis, especially in patients with diabetes ***(Ouwendijk et al., 2005).***

Aim of the Work

The aim of this study is to highlight the role of multislice CT angiography in the diagnosis of the peripheral arterial diseases of lower extremities.

Physical Principles of Multi-Detector Row CT

CT Generations:

During the 70's a rapid technical development could be observed, following the demand of radiology to reduce scan time. Starting with 1st and 2nd generations that combined rotational and translatory pencil beam and partial fan beam scanning followed by 3rd and 4th generation full continuous rotation around 360° (Figure1) ***(Mahadevappa et al.,2002).***

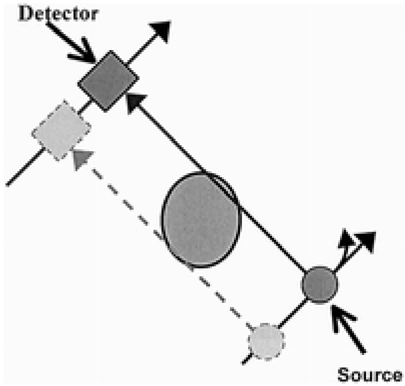


Figure (1a): Diagram of the first-generation CT scanner, which used a parallel x-ray beam with translate-rotate motion to acquire data ***(Mahadevappa et al.,2002).***

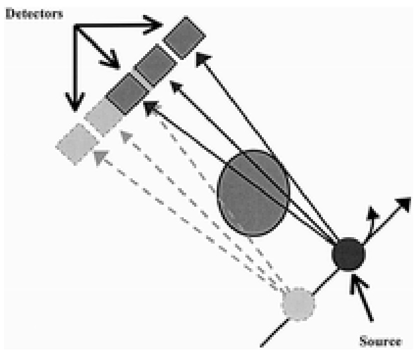


Figure (1b): Diagram of the second-generation CT scanner, which used translate-rotate motion to acquire data***(Mahadevappa et al.,2002).***

Figure (1c): Diagram of the third-generation CT scanner, which acquires data by rotating both the x-ray source with a wide fan beam geometry and the detectors around the patient. Hence, the geometry is called rotate-rotate motion ***(Mahadevappa et al.,2002).***

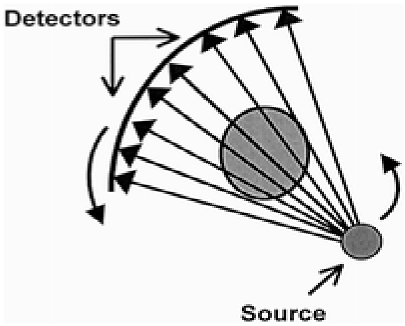
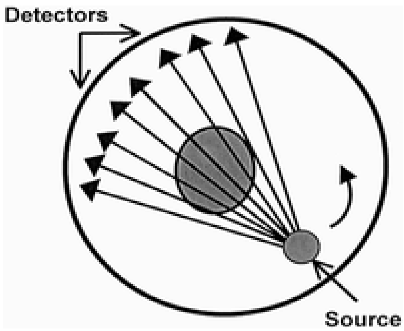


Figure (1d): Diagram of the fourth-generation CT scanner, which uses a stationary ring of detectors positioned around the patient. Only the x-ray source rotates with a wide fan beam geometry, while the detectors are stationary. Hence, the geometry is called rotate-stationary motion ***(Mahadevappa et al.,2002).***



Principles of Helical CT Scanners:

In older CT scanners, the X-ray source would move in a circular fashion to acquire a single 'slice', once the slice had been completed, the scanner table would move to position the patient for the next slice; meanwhile the X-ray source/detectors would reverse direction to avoid tangling their cables ***(Flohr et al., 2006).***

In helical CT the X-ray source are attached to a freely rotating gantry. During a scan, the table moves the patient smoothly through the scanner; the name derives from the helical path traced out by the X-ray beam. It was the development of two technologies that made helical CT practical: slip rings to transfer power and data on and off the rotating gantry, and the switched mode power supply powerful enough to supply the X-ray tube, but small enough to be installed on the gantry ***(Hoffman et al., 2005).***

The major advantage of helical scanning compared to the traditional shoot-and-step approach, is speed; a large volume can be covered in 20-60 seconds. This is advantageous for a number or reasons: 1) often the patient can hold their breath for the entire study, reducing motion artifacts, 2) it allows for more optimal use of intravenous contrast enhancement, and 3) the study is quicker than the equivalent conventional CT permitting the use of higher resolution acquisitions in the same study time ***(Elliot and Fishman, 2006).***

The data obtained from spiral CT is often well-suited for 3D imaging because of the lack of motion mis-registration and the increased out of plane resolution. These major advantages led to the rapid rise of helical CT as the most popular type of CT technology ***(Hoffman et al., 2005).***

Principles of multi-slice CT:

Multislice CT scanners are similar in concept to the helical or spiral CT but there are multiple detector rings. It began with two rings in the mid nineties, with a 2 solid state ring model designed and built by Elscint (Haifa) called CT TWIN, with one second rotation (1993): It was followed by other manufacturers. Later, it was presented 4, 8, 16, 32, 40 and 64 detector rings, with increasing rotation speeds. Current models (2007) have up to 3 rotations per second, and isotropic resolution of 0.35 mm voxels with z-axis scan speed of up to 18 cm/s ***(Elliot and Fishman, 2006).***

This resolution exceeds that of High Resolution CT techniques with single-slice scanners, yet it is practical to scan adjacent, or overlapping, slices-however, image noise and radiation exposure significantly limit the use of such resolutions ***(Hoffman et al., 2005).***

The major benefit of multi-slice CT is the increased speed of volume coverage. This allows large volumes to be scanned at the optimal time following intravenous contrast administration; this has particularly benefitted CT angiography techniques-which rely heavily on precise timing to ensure good demonstration of arteries ***(Marc-Kock et al., 2007)***.

Detector Rows:

The conventional single-slice helical CT scanner has one ray tube and a single row of detectors. This detector row contains 500–900 detector elements, which describe an arc in the transverse (axial or x-y) plane, providing one channel of spatial data. The multi-detector row CT scanner has one x-ray tube and multiple rows of detectors along the longitudinal (z) axis of the patient. Each row has 500–900 elements, and many rows together create a two-dimensional curved array containing thousands of detector elements, which are connected to four up to sixty four data acquisition systems that generate four to sixty four CT slices in each gantry rotation ***(Hoffman et al., 2005).***

At RSNA 2007, Philips announced a 128x2-slice scanner with a flying focus having 8 cm coverage per rotation while Toshiba announced a "dynamic volume" scanner based on 320 slices having 16 cm coverage per rotation ***(Marc-Kock et al., 2007)***.

Detector Array Design:

To register four slices simultaneously, a minimum of four detectors must be placed side by side along the Z-axis, but theoretically this will give us a machine that gives four slices of fixed section thickness that can not be changed. So, to offer a choice of several section thicknesses, more than four detector elements along the Z-axis are required ***(Rydberg et al., 2000).***

Three major detectors designs are used:

(1) Matrix detectors: where all detectors are of the same size. There is 16 identical detectors arranged side by side in the Z-axis, each one of them is 1.25 mm making it covering a distance of 20 mm. (General Electric)

(2) Adaptive array detectors: where they vary from thinner inside to thicker outside. There is 8 detectors, varying in size from 1 mm to 5 mm. They have a mirror image arrangement with the 1mm detector in the middle, then the 1.5 mm detector, then the 2.5 mm detector, and finally the 5 mm detector. These detectors arrangement cover also 20 mm in the Z-axis direction. (Siemens and Philips)

(3) Hybrid detectors: where usually two sizes are used with the thinner detectors located centrally. There are 34 detectors, 30 of them are 1 mm in length and the other 4 detectors are 0.5 mm in length. They are arranged with the smaller 4 detectors in the middle and other 30 on both sides, covering a distance of 32mm in the Z-axis direction. (*TOSHIBA*) ***(Rydberg et al., 2000).***

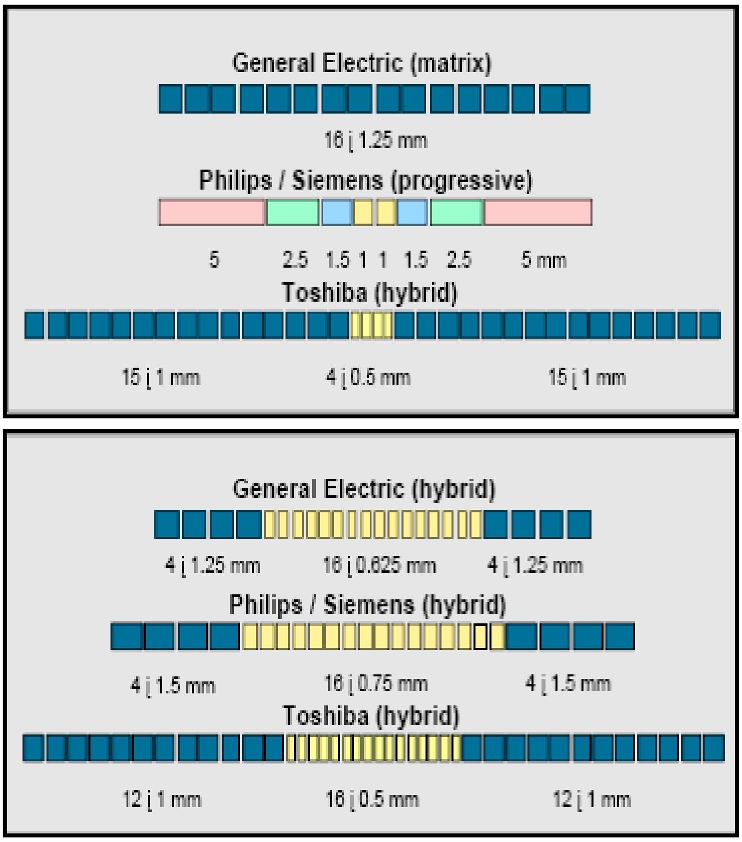


Figure (2): Detector array design of MSCT scanners. The layout of four-slice scanners (above) differs significantly from manufacturer to manufacturer, offering specific advantage and drawbacks. With 16-slice (below) scanners, all manufacturers have made use of hybrid ***(Kundra and Silverman, 2003).***

With 16-slice scanners, all manufacturers employed a hybrid layout, allowing for submilli-meter acquisition in 16-slice mode. Only the size of the smallest detector elements and the total width of the array differ, with each manufacturer claiming to offer the most optimal design. However, the question what is optimal depends on all aspects involved (z-resolution, volume coverage, dose), not only one (e.g. z-resolution). As in daily life, the optimum is the result of the best compromise. This becomes evident in cardiac CT, which is the most demanding new MSCT application ***(Flohr et al., 2004)*** .

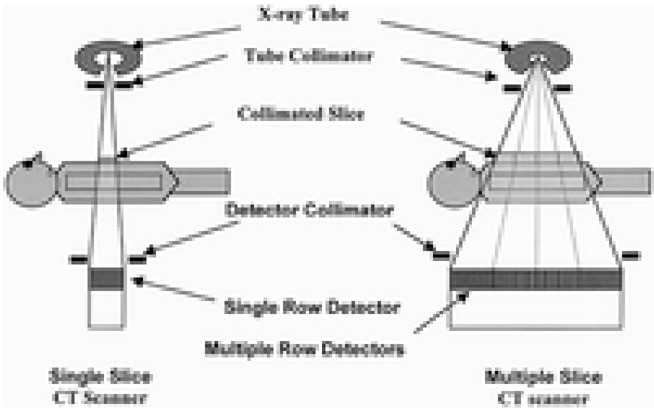


Figure (3): Diagram shows the difference between single-row detector and multiple-row detector CT designs. The multiple-row detector array shown is asymmetrical and represents that of one particular manufacturer ***(Mahadevappa et al.,2002).***

By increasing the number of CT scanner detector rows, data acquisition capability dramatically increases while greatly improving the efficiency of x-ray tubes ***(Mahadevappa et al.,2002).***

Further developments in scanner rotational speeds and tube outputs have made isotropic resolution a practical possibility with even better improvements on the horizon ***(Mahesh, 2002).***

Current multiple-row detector scanners can scan large 40-cm volume lengths in less than 30 seconds with near-isotropic resolution and image quality that could not be envisioned at the time of Hounsfield's invention ***(Mahadevappa et al., 2002).***

Helical Pitch:

With single-row detector helical CT scanners, the concept of pitch is straightforward. With the beam width given by W (in millimeters) and the table travel per gantry rotation defined as T (in millimeters), pitch and more specifically the beam pitch is defined as follows (Figure 4).

$$\text{Beam Pitch} = \frac{T}{W}. \qquad (6)$$

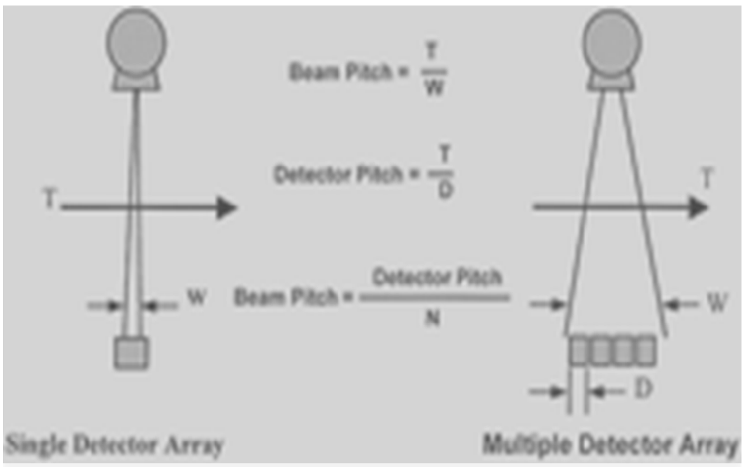


Figure (4): Diagram shows the concepts of beam pitch and detector pitch. Beam pitch is consistent with the previous notion of pitch used in single-row detector helical CT and works well for multiple-row detector CT scanners as well . D = detector width, N = number of active detectors, T = table travel per gantry rotation, W = beam width ***(Mahadevappa et al.,2002).***

With the introduction of multiple-row detector CT scanners, ambiguity arises in terms of the definition of pitch, since different manufacturers use different definitions of pitch ,which has resulted in much confusion ***(Silverman et al., 2001).***

Consequently, beam pitch needs to be distinguished from detector pitch, which is defined as follows:

$$\text{Detector Pitch} = \frac{T}{D}, \qquad (7)$$

where D is the detector width in millimeters ,If the x-ray beam is collimated to N active detectors in a multiple-row detector CT scanner, the relationship between beam pitch and collimator pitch is as follows:

$$\text{Beam Pitch} = \frac{\text{Detector Pitch}}{N}. \qquad (8)$$

The use of beam pitch is applicable equally to both single-row detector helical CT and multiple-row detector CT and eliminates the confusion existing between the relationship of radiation dose and various manufacturers' defined pitch ***(Mahadevappa et al., 2002).***

Collimation:

The concept of collimation is relatively straight-forward with single–detector row CT. With the single–detector row technique, collimation refers to the act of controlling beam size with a metallic aperture near the tube, thereby determining the amount of tissue exposed to the x-ray beam as the tube rotates around the patient ***(Napel,1998).***

Thus, in single–detector row CT, there is a direct relationship between collimation and section thickness. Because the term collimation may be used in several different ways in multi–detector row CT, it is important to distinguish between beam collimation and section collimation **(*Neal et al., 2005).***

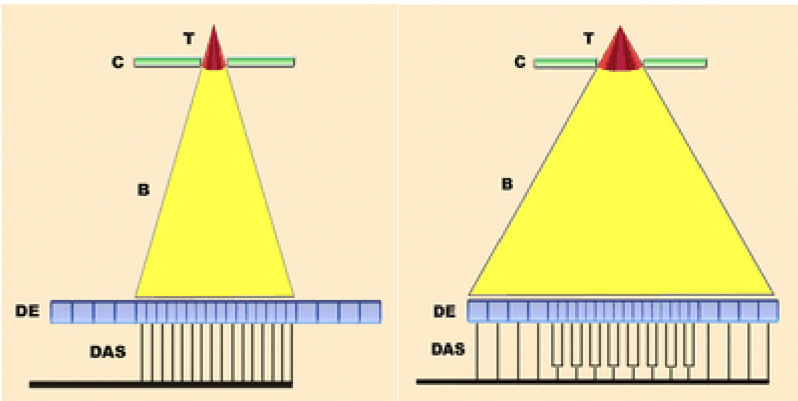
Beam Collimation:

Beam collimation is the application of the same concept of collimation from single–detector row CT to multi–detector row CT. A collimator near the x-ray tube is adjusted to determine the size of the beam directed through the patient. Because multiple channels of data are acquired simultaneously, beam collimation is usually larger than reconstructed section thickness ***(Hu,1999)***.

When a 16-channel scanner is used, for example, one of two settings is selected for most applications (Figure 5). Narrow collimation exposes only the central small detector elements. The data acquisition system controls the circuits that transmit data from the detector and collects data only from the intended elements ***(Prokop et al., 2003).***

Wider collimation may expose the entire detector array. Unlike narrow collimation, in which the central elements are sampled individually, with wide collimation the 16 central elements are paired or binned, providing data as if they were eight larger elements ***(Cody et al., 2003).***

The four additional larger elements on each end of the detector array then complete the total of 16 channels of data. In this example, beam collimation would be 10 mm in the narrow setting or 20 mm in the wide setting.



a b

Figure (5): Beam collimation in 16-section CT. B = beam, C= collimator, DAS=data acquisition system, DE=detector elements, T=tube. (a) Narrow collimation exposes only the small central detector elements. (b) Wide collimation exposes all of the detector elements. The small central